THE NATIONAL INSTITUTE OF INDUSTRIAL PSYCHOLOGY
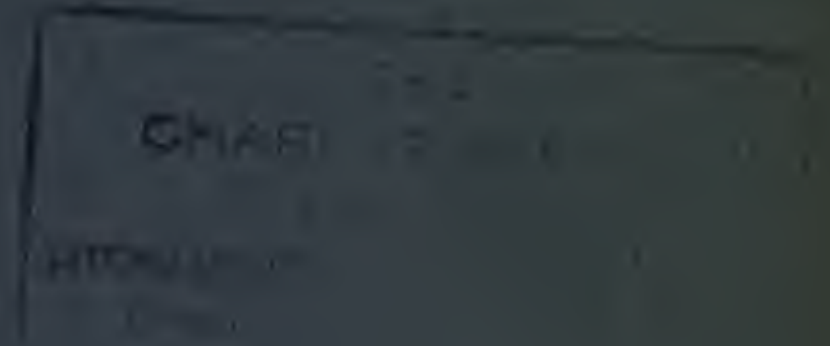
TESTS FOR ENGINEERING APPRENTICES

A Validation Study

BY

C. B. FRISBY, D. F. VINCENT and RUTH LANCASHIRE

———

TESTS FOR ENGINEERING APPRENTICES

A Validation Study

BY

C. B. FRISBY, D. F. VINCENT and RUTH LANCASHIRE

CONTENTS

TESTS FOR ENGINEERING APPRENTICES
A Validation Study

INTRODUCTION

BETWEEN 1942 and 1945 the National Institute of Industrial Psychology built up a battery of tests for use in the selection of engineering apprentices. With the co-operation of several companies, these tests were given to groups of apprentices in training, each company distinguishing between groups of apprentices above average performance and groups of apprentices below average performance. In each of the companies there was found to be a relationship between performance at the tests and performance during apprentice training. It was, of course, recognised that this gave only an approximate estimate of the value of the tests, but the results were sufficiently encouraging to lead the Institute to introduce this battery of tests to companies which, in subsequent years, sought its advice on the means for improving their procedure for selecting engineering apprentices.

With the passage of time, certain modifications were made to the test battery in the light of experience, but it has been the Institute's aim to undertake a much more thorough-going evaluation of the tests when this was possible. Evaluation is difficult because apprenticeship normally lasts five years, and the intake of apprentices by most of the companies which had been using the tests was relatively small. However, in 1952 visits were paid to a number of the companies concerned to see what data could be collected about the test results of candidates for apprenticeship, and about the subsequent performance during training of those selected. These visits showed, first, that in most companies the number of apprentices who had completed their time following the installation of the tests was quite small. They showed, too, that although records of attainment in technical college examinations were available, assessments of the boys' shop work would present even more than the usual difficulty in measuring performance on the job. The most that could be hoped for in this respect was an assessment of the apprentice in general terms, perhaps on a five-point scale, by the apprentice supervisor or the personnel department.

It was decided that in spite of these difficulties the inquiry should not be abandoned, and companies were approached again in 1956 with a request for further co-operation in providing information about their apprentices. Thirty companies offered the necessary facilities.

THE DATA

THE COMPANIES

The companies which provided the data on which this report is based are located in different parts of the country. Most are concerned with some branch of the engineering industry, and there are wide differences in their products, with a range from scientific instruments to heavy machinery. Certain of the companies do not make engineering products, and the engineering tradesmen whom they employ are engaged entirely on maintenance or construction work.

Companies differed in the number of years for which they had been using the Institute's tests. There were differences, also, in the annual intake of apprentices, in the total number of apprentices under training at one time, and in the way in which apprentice training was organised.

A study of the data revealed that there were important differences in the proportion of apprentices achieving a recognised attainment at the technical college, for example City and Guilds Intermediate, City and Guilds Final, Ordinary National Certificate, Higher National Certificate, between the companies. These differences might have arisen from a number of different factors, but it was the impression of the investigators that the most important must have been the degree of encouragement towards success in technical college which was provided by the company and its officials. In discussions with these officials it became clear that in some companies a great deal of weight was attached to the attainment of a recognised qualification by the apprentice, while in others this was not regarded as of importance. In an extreme case it might even be regarded as a disadvantage for many boys to obtain higher qualifications on the grounds that they would then not be content to remain with the company as craftsmen.

THE TESTS

In all, fourteen tests had been used in the thirty companies. They were:—

Verbal intelligence
  Group Test 33
  Group Test 36

Non-verbal intelligence
  Group Test 70
  Group Test 70/1
  Group Test 70/23

Spatial Judgment
  Group Test 80
  Group Test 80A
  Form Relations

Arithmetic
  Group Test 60E
  Group Test E.A.2

Mechanical
  Vincent Mechanical Models
  N.I.I.P. 'Stenquist' Assembly Test
  Mechanical Information Test

Manual Dexterity
  R. V. Manual Test

A description of these tests is given in Appendix A.

All the tests had not been used by all companies. Each company had, however, used at least one verbal intelligence test, one non-verbal intelligence test, one spatial judgment test, and one mechanical aptitude test. All but four companies had used two mechanical aptitude tests and all but four had also used the R. V. Manual Test.

MATERIAL COLLECTED

The information sought from the company consisted of the name of the apprentice, type of school he had attended, the date on which he had been tested, and his age at that date, his scores on the tests he had taken, the date on which his apprenticeship was completed, his highest achievement at the technical college in terms of examination passed at that time, and an assessment of his performance during his apprenticeship made by the apprentice supervisor or some other officer of the company. In addition, information was sought about test

scores of candidates for apprenticeship who had not been accepted by the company.

The information from three companies had to be discarded because of some inadequacy; in one case no information on academic attainment was available, in a second the apprenticeship scheme had been abandoned on the transfer of a factory to new owners, and in the third, sixty per cent of the boys had apparently passed no academic examination of any kind. In eight companies the group of time-expired apprentices was too small (26 or less) for separate analysis.

The position can be summarised as follows:—

Companies offering facilities for the inquiry	30
Companies whose data were included in the main statistical analysis	19
Apprentice candidates for whom test scores were available	5,450
Apprentices completing their time:—	
Craft apprentices	1,862
Student apprentices	303
Apprentices included in the main statistical analysis:—	
Craft apprentices	1,661
Student apprentices	260

Arrangements for the collection of data were made by members of the Institute's staff in visits to the firms concerned. On some occasions they extracted the information from the records themselves, and on others the company kindly arranged for copies to be made of their records.

CRITERIA OF PERFORMANCE DURING APPRENTICESHIP

It was hoped to obtain two criteria by which the boy's performance during his apprenticeship could be judged, and which could be compared with performance at the tests before he was accepted for apprenticeship. These were: (i) his attainment at technical college and (ii) an assessment of his work in the firm made by the apprentice supervisor or by some other official. Although the Institute stressed that in making this assessment officials should concentrate on the quality of his practical work, ignoring his performance at technical college and seeking to be uninfluenced by matters such as attendance, punctuality and disposition, it is common knowledge that such assessments are always to some extent contaminated by these factors.

At the technical college boys had followed either National Certificate courses or City and Guilds courses. A certain number of them had been allotted to a preliminary course in order to bring them up to the general educational level considered desirable by the technical college authorities before they began the technical courses. Most of the boys taking the National and City and Guilds courses followed the Mechanical Engineering course. A certain number did Electrical Engineering, a very much smaller number followed one or other specialised course. The numbers were such that it was not practicable to attempt an analysis by course subject, and consequently it was decided to treat all National courses as equivalent and all City and Guilds courses as equivalent, although it was known that in fact there are in certain courses, barely if at all represented in the data, marked differences in the standards involved.

Since in an analysis of the data for any one company the numbers were not normally sufficient to permit separate analysis for boys on National courses and those on City and Guilds courses, it was necessary to combine attainments on the two types of course as a common scale. The combination had of necessity to be an arbitrary one, but the Institute sought advice from people with special knowledge in the field of technical education and in the light of the advice received it was decided to adopt the scale set out below:—

Grade	Most Advanced Achievement
0	No success in any examination.
1	Successfully completed preliminary year.
2	Successfully completed City and Guilds Year 1.
3	Successfully completed City and Guilds Year 2 or O.N.C. S.1.

Grade	*Most Advanced Achievement*
4	Successfully completed City and Guilds Year 3 or O.N.C. S.2.
5	Successfully completed City and Guilds Year 4.
6	Successfully completed City and Guilds Year 5 or O.N.C. Final.
7	Successfully completed H.N.C. A.1.
8	Successfully completed H.N.C. A.2.
9	Achieved some qualification higher than H.N.C. A.2.

For the purpose of allotting an apprentice a point on this scale, his achievement at the time when he completed his apprenticeship had to be taken.

It is evident that this academic criterion scale has certain weaknesses. As has been said, it is arbitrary, in that it is impossible to obtain an objective evaluation of the equivalents of National Certificate courses and City and Guilds courses, if only for the reason that the ground covered by the courses is somewhat different. Secondly, an examination passed at the earliest possible time does not indicate the same ability as one passed at the second or third attempt,

and differentiation was not possible. Thirdly, there is the fact that the examinations in the National Certificate courses may well differ to some extent between technical colleges.

Not all the companies were able to provide ratings for the apprentices' performance on the shop floor. In some cases there had been changes in the officials best placed to make these assessments, so that the man then in office had no knowledge of earlier apprentices. In other cases officials were unwilling to make an assessment which had to be dependent mainly on memory of performance of boys whose apprenticeship might have been completed several years earlier. In some firms the Institute's investigators had access to reports on progress, completed at annual or other intervals throughout each boy's apprenticeship. In these cases the investigators themselves made an assessment on each boy from their interpretation of the records, and discussed their gradings with the firm's officials. Care was taken to ensure a normal distribution of boys among the five grades of a scale from A to E. For convenience this criterion is referred to in this report as the supervisor's rating.

PROCEDURE FOR ANALYSIS

It was decided to conduct the analysis on two different lines. The major task was the comparison, by means of correlation, of performance at tests with academic attainment and the rating for work on the shop-floor. Secondly, it was decided to examine the proportion of boys making scores on the tests within certain ranges who achieved Ordinary National Certificate, Higher National Certificate, the City and Guilds Intermediate or the City and Guilds Final. A correlational analysis is the common method employed in an inquiry such as this designed to investigate the value of certain tests in a selection situation. It gives a picture of the relationship between test performance and job performance which may require some explanation for those unfamiliar with the statistics used in psychology*. The second

analysis has the merit of showing directly the success achieved in any one of the chosen academic standards by boys whose scores on the tests fell within certain ranges.

The comparison of test performance with job performance was the primary purpose of this inquiry. The data which were collected did, however, yield certain other information likely to be of interest to those concerned with technical education. In Appendix C are figures showing the proportions of the whole group of 2,165 apprentices reaching different levels of attainment in the National Certificate and City and Guilds courses, with a supplementary analysis of attainment according to type of previous secondary education for a sample of 906 apprentices.

*See Appendix B for a graphical explanation of correlation

THE CORRELATIONAL ANALYSIS

In addition to the differences between the companies which have already been referred to on page 2, there were others. These include the ratio of applicants to apprenticeship vacancies, the quality of the applicants, and the screening procedures employed by the companies in deciding which of the applicants might be considered candidates and submitted to the full selection procedure including the tests. The possible effects of all these differences led to the conclusion that in the correlational analysis it would be necessary to make the calculations for each firm separately. It was also decided that the analysis should be made separately for craft apprentices and student apprentices. The differences between the companies which can be expressed numerically are shown in Tables D1(A) and D1(B) in the Statistical Appendix D.

The first stage of the analysis for each firm was to calculate the product moment correlation coefficient between each of the tests used in that firm and the academic criterion and the supervisors' ratings. The correlations so calculated are set out in Tables D3(A) and D3(B) of Appendix D. The correlations for the academic criterion will be discussed first.

THE ACADEMIC CRITERION

There was found to be very considerable variation from firm to firm in the value of the coefficients. The range was from $+\cdot64$ down to values not significantly different from zero. These differences could not be taken to mean that the tests were having greatly different prognostic value in different firms without a further examination of the situation. It must be remembered that the companies had been using the tests as part of the selection procedure, so that a boy's performance on the tests had been a factor in deciding whether he should be offered an apprenticeship. In such a situation it is to be expected that the range of scores of the selected apprentices will be very much narrower than that of the candidates for apprenticeship. The effect of a restriction in the range of the scores is to reduce the value of the correlation between test score and criterion from the value that would have been obtained if the range of scores of selected apprentices had been the same as that of the candidates; in other words, if no notice had been taken of test performance. In assessing the value of tests in a selection procedure, the aim is to discover the true relationship between performance on the tests and performance on the criterion, which can only be found directly if all those tested are allowed to enter employment so that a full range of ability as measured by the tests is represented in the working group.

There are, however, statistical procedures which make it possible to estimate from the correlations obtained directly, as set out in Tables D3(A) and D3(B) of Appendix D, the value of the correlations which would be obtained from the desirable procedure. This involves being able to estimate the amount by which the range of test scores had been reduced among the apprentices engaged and the amount by which the range of performance on the criterion had also been reduced. Such procedures involve assumptions which can be only approximately true and they introduce some risk of exaggerating the correlations between tests and criterion. Despite this, there is no doubt that in cases like this they give a truer picture of existing relationships than the uncorrected correlations.

It was decided that in order to make this statistical adjustment and to arrive at estimates of the true correlations between test performance and the criterion, the standard range of performance on the tests which should be adopted was that shown by applicants for apprenticeship. Test scores for applicants had been available in 15 out of the 19 companies whose data were included in the main statistical analysis. Those referred to more than 5,000 applicants in total, but some tests had been given to small groups of applicants in one or two companies only. In the case of these tests, the standard range of performance adopted was

taken from figures already in the Institute's files. Details of the procedure followed will be found in Appendix D.

The application of the correctional procedure to the raw correlations led to the results shown in Tables IA and IB.

TABLE IA

CORRELATIONS BETWEEN TESTS AND ACADEMIC CRITERION CORRECTED FOR RESTRICTION OF RANGE

CRAFT APPRENTICES

FIRM	VERBAL INTELLIGENCE		NON-VERBAL INTELLIGENCE			SPATIAL JUDGMENT			ARITHMETIC		MECHANICAL			MANUAL DEXTERITY
	33	36	70	70/1	70/23	80	80A	F.R.	60E	E.A.2	V.M.	STEN.	M.I.	R.V.
A ..	·65				·72		·67				·63			
B ..		·71			·62		·50			·78	·58	·22		·40
C ..		·73			·58		·67				·53	·36		·40
D ..	·65				·56		·59		·81		·60	·47		·29
E ..	·58				·57			·38			·56	·41		·35
F ..	·55				·50		·29			·55	·63	·49		·28
G ..	·70			·84	·62		·73			·70	·64	·21		·43
H ..	·69		·79				·46			·41	·55	·67	·55	
I ..	·59			·56		·56	·49		·63		·49			
J ..	·63					·60	·51				·77			
K ..	·70				·43		·54				·46			·37
L ..	·52				·44		·61			·59	·64	·30		·39
M ..	·60				·60		·46				·54	·46		·30
N ..	·61				·63		·36				·56	·26		·47
O ..	·61				·46			·57			·66	·68		·39
P ..	·59			·60	·53		·54			·65	·47	·26	·75	·19
Q ..	·67				·60		·49			·71	·61	·55		·27
WEIGHTED AVERAGE	·63	·73		·66	·57	·58	·46	·56	·75	·72	·59	·42	·68	·35

TABLE IB

CORRELATIONS BETWEEN TESTS AND ACADEMIC CRITERION CORRECTED FOR RESTRICTION OF RANGE

STUDENT APPRENTICES

FIRM	VERBAL INTELLIGENCE		NON-VERBAL INTELLIGENCE			SPATIAL JUDGMENT			ARITHMETIC		MECHANICAL			MANUAL DEXTERITY
	33	36	70	70/1	70/23	80	80A	F.R.	60E	E.A.2	V.M.	STEN.	M.I.	R.V.
D ..	·82				·77		·65		·84		·62	·63		·28
H ..	·64			·67			·41			·68	·71	·50	·19	
J ..	·77						·63	·73			·77			
N ..	·77				·68		·46				·82			·38
R ..	·44						·27				·51	·38		·13
S ..	·72				·67		·53		·64		·68	·66		·30
WEIGHTED AVERAGE	·73				·72		·54		·77		·72	·55		·29

It will be seen that while there are still some differences in the values of the coefficients between the firms, they are in the main not large. Though there are undoubtedly real

differences in the conditions in the different firms which would justify differences in the size of these correlations, there is statistical evidence which points to the fact that the differences must be attributed largely to sampling errors. The best estimate of the general relationship between test performance and the academic criterion is provided by the weighted average correlation for all firms. This is shown in the last lines of Tables IA and IB.

The conclusion to be drawn from these tables is that each of the tests is related to performance on the criterion but that the relationship in the case of the R.V. Manual Dexterity Test is small. The Stenquist Test also appears to have a smaller relationship than the other tests. It is unsafe to draw conclusions about differences between correlations for student and craft apprentices, since there were only six groups of student apprentices and the numbers in these groups were small. Furthermore, the distribution of the student apprentices on the academic criterion scale was not a normal one, and this introduces an error into the correlations. The error of the weighted average of the correlation for the student apprentices is therefore decidedly larger than is the case with the craft apprentices. This means that numerical differences between the averages have to be treated with more reserve.

The next stage in the analysis was to determine whether the diagnostic value of the battery of tests as a whole would be increased by giving different weights to certain tests in the battery. For this purpose only data from companies which had used precisely the same battery of tests could be dealt with. Five firms (F, G, L, P and Q) were selected, as these had all used Group Test 33, Group Test 70/23, the Arithmetic Test E.A.2, the Form Relations Test, the Vincent Mechanical Models Test and the Stenquist Test. The total group of apprentices thus covered was 478. It was necessary at this stage to pool the data from these five firms, to make the number of cases large enough to justify the statistical method to be employed. The inter-correlations between the six tests and

between the tests and the academic criterion were calculated (see Table D5 in Appendix D). This procedure yielded a multiple correlation coefficient of ·75, which is the highest possible correlation between test performance and the academic criterion which can be obtained from the data with the best possible weighting of the individual scores. These weights are, of course, fractional quantities, very inconvenient in use, and when they are rounded off to the nearest whole number the multiple correlation is found to be reduced by only ·01 to ·74, a negligible difference. In fact when equal weight was given to each test and the multiple correlation recalculated there was found to be a further decrease of only ·01 to the figure of ·73. The adoption of a precise weighting procedure therefore yields no practical advantage over the simple arrangement of giving equal weight to each test. In these calculations the R.V. Manual Test was omitted because of the relative smallness of its correlation with the criterion. A calculation of the multiple correlation coefficient was made, omitting the Stenquist Test but giving equal weight to Group Test 33, Group Test 70/23, E.A.2, the Form Relations Test and the Vincent Mechanical Models Test. This was found to be also ·73. Thus it is evident that the Stenquist Test, though of a certain value by itself, does not add value to the battery as a whole when performance at the technical college is taken as the criterion.

SUPERVISORS' RATINGS

The raw correlations between performance at the tests and the supervisors' ratings are shown in Tables IIA and IIB below. It will be noted that these calculations could be made for only eleven firms. It is not possible in the case of these correlations to make corrections as was done with the correlations with the criterion of performance at technical college. All that one can say is that if it had been possible to correct for restriction of range it is not likely that correlations higher than the highest uncorrected figures, namely ·38, ·49, ·50, would have been obtained.

TABLE IIA
CORRELATIONS WITH SUPERVISORS' RATINGS
CRAFT APPRENTICES

FIRM	TEST													
	33	36	70	70/1	70/23	80	80A	F.R.	60E	E.A.2	V.M.	STEN.	M.I.	R.V.
A ..	·33				·38			·17			·32			
C ..		·32			·29			·31			·25	·26		·05
D ..	·18				·12			·17			·29	·14		·24
F ..	·25				·23			·20		·50	·30	·38		·14
G ..	·16			·19	·16			·13		·16	·23	·37		·10
H ..	·32		·30					·27		·49	−·04	·06	·07	
J ..	·03					·14		·09			·11			
L ..	·09				·18			·24		·27	·19	·13		·13
M ..	·23				·17			·05			·19	−.02		·00
P ..	·02			·13	·03			·09		·21	·04	−.21	·07	−·16
Q ..	−·11				·13			·06		·19	·05	·06		·20
WEIGHTED AVERAGE	·13			·15	·19			·14		·29	·19	·20	·07	·09

TABLE IIB
CORRELATIONS WITH SUPERVISORS' RATINGS
STUDENT APPRENTICES

FIRM	TEST													
	33	36	70	70/1	70/23	80	80A	F.R.	60E	E.A.2	V.M.	STEN.	M.I.	R.V.
D ..	·17				·19			·24			·08	·27		−·02
H ..	·04		−·02					−·10		−·02	−·20	·07	·21	
J ..	·22							·07			·09			

PERFORMANCE BY FOUR ACADEMIC CRITERIA OF BOYS
MAKING CERTAIN SCORES ON THE TESTS

For the purpose of this analysis, it was necessary to treat the apprentices, both craft and student, of all firms as one group, since the number in no one firm was sufficiently large to give any significant result. It is not possible to make an assessment of the effect on the results of this analysis of the fact that boys of similar attainments in terms of test performance were subjected to different conditions in their technical education; differences existed in the measure of encouragement given by the firm, in ease of access to the college, and possibly in the teaching

and facilities at different technical colleges. It might be argued that, if all had received equally favourable conditions in which to learn, those with the higher test performances would, if the tests were really related to success at the technical college, have achieved still higher standards of technical education than they did in fact achieve. As opposed to this it might be said that, where encouragement from others was lacking, self-encouragement provided by early success of those with higher natural aptitudes should have accentuated the gap in performance be-

tween them and those less well endowed. On balance it appears probable that the results obtained by treating all the time-expired apprentices as one group will underestimate the degree of relationship between test performance and academic attainment.

The results of all the tests could not be analysed in this way, since for certain of them there were not large enough groups of apprentices. The analysis was undertaken for five tests, and the results are set out in Tables IIIA, B, C, D and E. These tables show the number of boys obtaining scores within certain ranges on each of the tests, the numbers being divided into three groups. There is firstly that of boys who could show no record of any achievement at technical college, and on whom it was not possible to be certain whether they were supposed to be working on a City and Guilds or a National course. Secondly and thirdly there are those who were known to be working for the City and Guilds or National courses because they had passed some examination at some stage of the course. The next two columns show the proportion of those known to be taking City and Guilds courses who passed the Intermediate or Final examinations. The final two columns show the proportions of those doing National courses who passed the Ordinary National Certificate and the Higher National Certificate. In the last line of the table is shown the proportion of the whole groups who obtained Intermediate City and Guilds, Final City and Guilds, Ordinary National Certificate and Higher National Certificate.

In general, the results of this analysis confirm those of the correlational analysis in which the combined academic criterion was used. The tables show a steady decline in the proportion of those reaching one of the recognised standards in the examinations as the scores on the tests become lower. There is some irregularity at the top and bottom of the tables, but it has to be remembered that at these points the percentages are on small base numbers. The fact that a few boys with very low attainments on the tests nevertheless achieved academic success must indicate that their test performances were an unreliable indicator of their aptitudes. No psychologist would claim that the results, of even reliable and valid tests, are always a precise indication of aptitude, since they may be invalidated by such things as the indisposition of the candidate, failure in the test administration to enlist the full co-operation of the candidate or errors of administration.

TABLE IIIA
CRAFT AND STUDENT APPRENTICES COMBINED
GROUP TEST 33

SCORES	PASSED NO EXAMINATION	PASSED SOME EXAMINATION OF THE CITY AND GUILDS	PASSED SOME EXAMINATION OF THE NAT. CERT. COURSE	OF THOSE WITH SOME ATTAINMENT IN CITY AND GUILDS: PERCENTAGE GETTING		OF THOSE WITH SOME ATTAINMENT IN NAT. CERT. COURSE: PERCENTAGE GETTING	
				INTER.	FINAL	O.N.C.	H.N.C.
Over 160 ..			20			85	65
151—160 ..		1	32	100	0	78	28
141—150 ..	1	8	70	100	37	79	29
131—140 ..	5	14	159	86	36	70	28
121—130 ..	5	30	195	67	13	67	21
111—120 ..	12	45	174	78	18	52	17
101—110 ..	14	53	178	64	19	52	13
91—100 ..	10	48	147	60	19	35	7
81— 90 ..	17	45	77	60	18	42	6
71— 80 ..	15	17	43	41	6	28	5
Less than 71	37	28	31	57	7	42	13
TOTAL: ..	116	289	1,126	65	17	56	18

TABLE IIIB
CRAFT AND STUDENT APPRENTICES COMBINED
GROUP TEST 70/23

SCORES	PASSED NO EXAMINATION	PASSED SOME EXAMINATION OF THE CITY AND GUILDS	PASSED SOME EXAMINATION OF THE NAT. CERT. COURSE	OF THOSE WITH SOME ATTAINMENT IN CITY AND GUILDS: PERCENTAGE GETTING		OF THOSE WITH SOME ATTAINMENT IN NAT. CERT. COURSE: PERCENTAGE GETTING	
				INTER.	FINAL	O.N.C.	H.N.C.
46 and over ..			9			78	56
41—45 ..		6	48	100	0	79	42
36—40 ..	1	25	153	88	36	67	25
31—35 ..	13	73	233	81	25	57	17
26—30 ..	19	104	215	70	18	48	13
21—25 ..	22	75	112	43	8	45	8
16—20 ..	22	44	40	54	18	35	7
Less than 16	19	23	12	48	0	17	9
TOTAL: ..	96	350	822	65	17	55	18

TABLE IIIC
CRAFT AND STUDENT APPRENTICES COMBINED
FORM RELATIONS TEST

SCORES	PASSED NO EXAMINATION	PASSED SOME EXAMINATION OF THE CITY AND GUILDS	PASSED SOME EXAMINATION OF THE NAT. CERT. COURSE	OF THOSE WITH SOME ATTAINMENT IN CITY AND GUILDS: PERCENTAGE GETTING		OF THOSE WITH SOME ATTAINMENT IN NAT. CERT. COURSE: PERCENTAGE GETTING	
				INTER.	FINAL	O.N.C.	H.N.C.
56 and over ..		4	35	100	0	86	43
51—55 ..	2	4	54	100	25	76	28
46—50 ..	6	21	127	91	29	71	31
41—45 ..	6	40	193	78	32	60	20
36—40 ..	13	59	228	80	30	60	18
31—35 ..	25	70	249	59	10	56	16
26—30 ..	33	90	176	66	11	40	10
21—25 ..	26	66	94	38	5	36	7
Less than 21	17	30	19	53	7	37	5
TOTAL: ..	128	384	1,175	64	16	57	18

TABLE IIID
CRAFT AND STUDENT APPRENTICES COMBINED
VINCENT MECHANICAL MODELS TEST

SCORES	PASSED NO EXAMINATION	PASSED SOME EXAMINATION OF THE CITY AND GUILDS	PASSED SOME EXAMINATION OF THE NAT. CERT. COURSE	OF THOSE WITH SOME ATTAINMENT IN CITY AND GUILDS: PERCENTAGE GETTING		OF THOSE WITH SOME ATTAINMENT IN NAT. CERT. COURSE: PERCENTAGE GETTING	
				INTER.	FINAL	O.N.C.	H.N.C.
61 and over ..		3	16	100	33	75	25
56—60 ..	2	9	95	89	11	70	28
51—55 ..	5	17	198	76	29	72	27
46—50 ..	8	37	187	76	30	66	22
41—45 ..	9	36	139	72	19	64	24
36—40 ..	11	41	137	71	19	50	18
31—35 ..	13	48	103	65	17	45	10
26—30 ..	15	48	105	69	12	43	10
21—25 ..	15	36	69	78	11	42	7
16—20 ..	10	30	53	43	7	40	9
11—15 ..	11	30	26	47	13	23	0
6—10 ..	11	20	30	30	10	37	3
Less than 6 ..	13	23	13	48	13	31	8
TOTAL: ..	123	378	1,171	64	16	57	18

TABLE IIIE
CRAFT AND STUDENT APPRENTICES COMBINED
E.A.2.

SCORES	PASSED NO EXAMINATION	PASSED SOME EXAMINATION OF THE CITY AND GUILDS	PASSED SOME EXAMINATION OF THE NAT. CERT. COURSE	OF THOSE WITH SOME ATTAINMENT IN CITY AND GUILDS: PERCENTAGE GETTING		OF THOSE WITH SOME ATTAINMENT IN NAT. CERT. COURSE: PERCENTAGE GETTING	
				INTER.	FINAL	O.N.C.	H.N.C.
36 and over ..			10			90	20
31—35 ..	1	8	38	88	12	82	42
26—30 ..	1	53	137	98	38	79	25
21—25 ..	5	59	89	76	17	57	18
16—20 ..	5	40	31	87	22	42	3
Less than 16	5	20	11	60	15	18	0
TOTAL: ..	17	180	316	84	24	68	22

On the other hand the fact that some boys with very high test performances failed to achieve academic distinction reflects the fact that attainment is dependent on factors of interest, encouragement and motivation as well as on the qualities measured by the tests.

In order to parallel the correlational analysis undertaken for the five firms F, G, L, P and Q (see page 7), a separate study was made of the results of the boys apprenticed in these firms. The correlational analysis had shown that by giving equal weight to each of five tests, namely Group Test 33, Group Test 70/23, the Form Relations Test, the Vincent Mechanical Models Test, and Arithmetic Test E.A.2, a multiple correlation of practically the same order

as that derived from the seven tests with fractional weighting could be obtained. These five tests were therefore used, the scores being combined by translating all into convenient scales to give all tests approximately equal weight. The results are shown in Table IV. Some of the boys had not taken all the five tests, so a combined score could not be calculated for them. This reduced the number of apprentices whose performance could be analysed to 347. The numbers in each score group are naturally small, and there is some irregularity in the figures; once more there is a fairly steady decline in the proportion of boys obtaining the different academic qualifications as their combined score on the tests declines.

TABLE IV
SUMMARY OF ACADEMIC QUALIFICATIONS OF TIME-EXPIRED
CRAFT APPRENTICES FROM FIVE FIRMS TAKING STANDARD
BATTERY 33, 70/23, F.R., V.M. AND E.A.2 BEFORE ENTRY

COMBINED SCORE ON FIVE TESTS	PASSED NO EXAMINATION	PASSED SOME EXAMINATION OF THE CITY AND GUILDS	PASSED SOME EXAMINATION OF THE NAT. CERT. COURSE	OF THOSE WITH SOME ATTAINMENT IN CITY AND GUILDS PERCENTAGE GETTING		OF THOSE WITH SOME ATTAINMENT IN NAT. CERT. COURSE: PERCENTAGE GETTING	
				INTER.	FINAL	O.N.C.	H.N.C.
75 and over ..		1	15	100	0	87	67
70—74 ..		5	15	100	0	93	47
65—69 ..		9	29	100	33	69	21
60—64 ..	1	8	37	100	75	76	24
55—59 ..	2	20	37	90	45	78	22
50—54 ..	0	14	32	93	43	59	9
45—49 ..	1	13	38	77	23	53	11
40—44 ..	4	5	11	60	20	36	0
35—39 ..	1	8	11	87	25	18	0
30—34 ..	0	6	8	67	0	25	0
Less than 30	3	7	6	57	14	0	0
TOTAL: ..	12	96	239	85	32	63	20

CONCLUSIONS

The data available for this study were very far from ideal, as has been explained. The main difficulties may be recapitulated thus:—

(a) Not all firms used the same battery of tests. This was not the major difficulty, since virtually all firms used a battery of tests which included five basic types: verbal intelligence, non-verbal intelligence, spatial relations, mechanical aptitude and arithmetic.

(b) There were substantial differences between the nineteen firms in the level of academic achievements of their apprentices. The range for craft apprentices in mean score on the academic criterion scale was from 2·84 to 5·83. These differences were much greater than differences between the firms in terms of test performance by the apprentices, and must have been due in large part to different circumstances in the firms, the most important factor being probably the degree of encouragement given to boys to achieve academic qualifications.

(c) Differences between the firms made it necessary to undertake a separate analysis for each firm, with the result that the number of boys in any one group was not large.

(d) Because of the small numbers in the groups, attainments at the City and Guilds courses had to be equated with those on the National courses by an arbitrary academic criterion scale for the purpose of the correlational analysis.

(e) The second criterion of performance in the workshops was based on the supervisor's ratings or reports, but was not available for all cases and was of dubious value.

Despite the difficulties, the inquiry has yielded evidence that a group of tests of five types, namely verbal intelligence, non-verbal intelligence, spatial judgment, arithmetic and mechanical aptitude, can be of value in the selection of engineering apprentices. A marked relationship between performance on the tests and achievement at the technical college was shown. Failure to obtain an adequate criterion of shop work made it impossible to obtain a measure of the value of the tests from this point of view, but the evidence of the supervisors' ratings, meagre as it is, at least points to the conclusion that the tests are useful in this respect also. The importance of factors other than the abilities measured by the tests in the degree of academic success achieved by the apprentice was made very clear from the inquiry.

APPENDICES

APPENDIX A

TESTS USED

Group Tests 33 and 36

Intelligence tests having five sections, each consisting of verbal problems of different types.

Group Test 70

A non-verbal test of intelligence with three sections. The first involves the identification of a portion of one of five key figures. The second presents analogies in diagrammatic form, and the third consists of problems involving series.

Group Test 70/1

Section 1 of Group Test 70.

Group Test 70/23

Sections 2 and 3 of Group Test 70.

Group Test 80

A test of recognition of spatial relationships.

Group Test 80A

A revised edition of Group Test 80.

Form Relations Test (F.R.)

A test of recognition of spatial relationships.

Arithmetic Test 60E

A general purpose arithmetic test consisting of four rules questions and simple problems.

Arithmetic Test E.A.2

A rather more advanced arithmetic test with problems set in mechanical terms.

Vincent Mechanical Models Test (V.M.)

Eight working models are exhibited in turn with the mechanism concealed. A candidate has to select from a number of diagrams the mechanism which would produce the movement exhibited by the model.

N.I.I.P. Stenquist Test (Sten.)

An assembly test of the type known generically as Stenquist after its originator. A number of common objects which have been taken to pieces have to be reassembled.

Mechanical Information Test (M.I.)

A test of knowledge of names of tools and materials used in the home workshop. It is intended to reflect experience and interest in mechanical things.

R.V. Manual Test (R.V.)

Ball-bearings have to be taken one at a time from a tray and dropped through holes, first with forceps, secondly with a scoop and thirdly with the fingers alone.
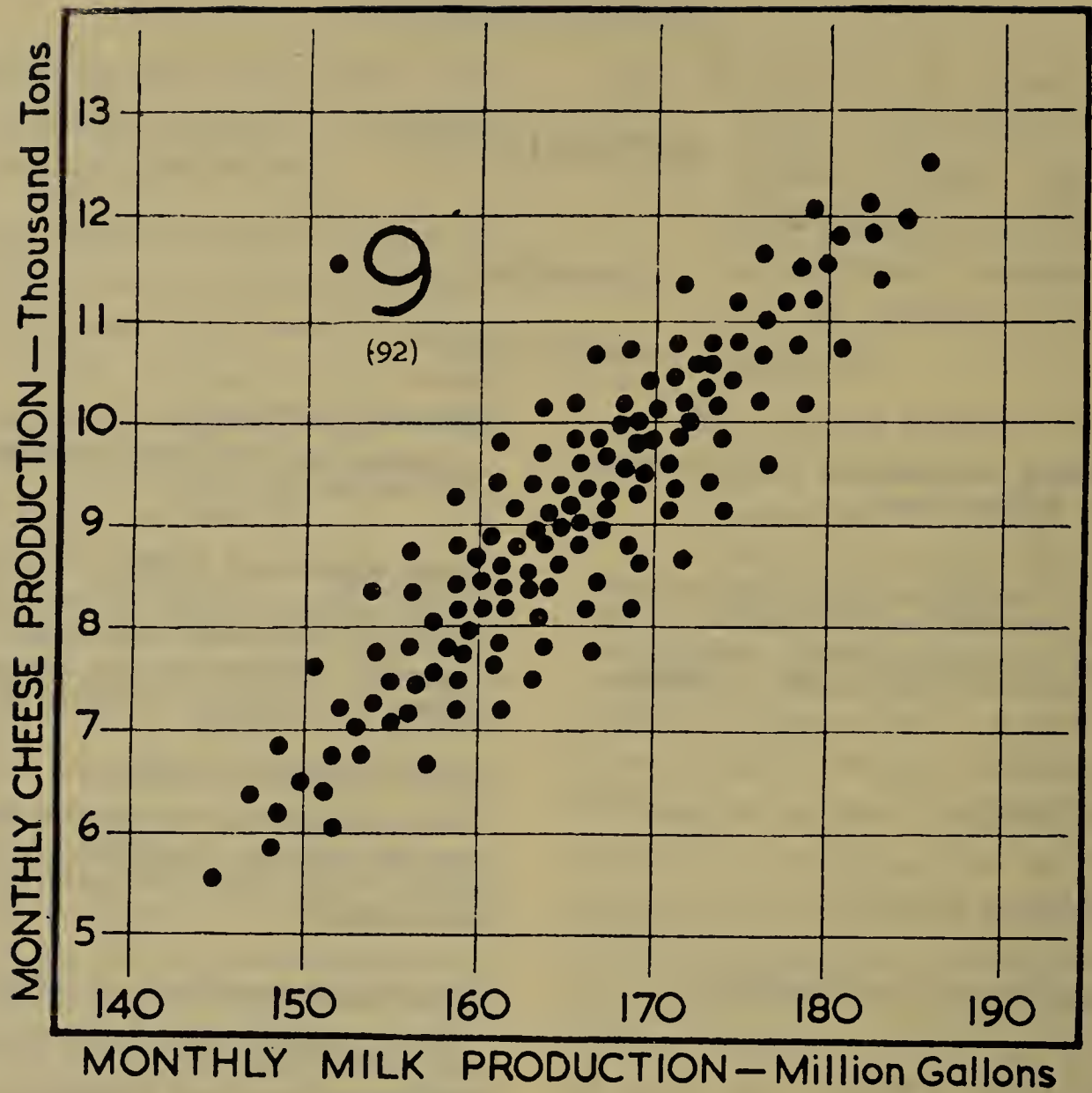
APPENDIX B

A GRAPHICAL EXPLANATION OF CORRELATION

Correlation is a statistical device for estimating the amount of agreement between two sets of measurements.

The Correlation Coefficient is a numerical expression of the amount of agreement. It varies between zero for no agreement at all (as in the case of births and deaths per month) and unity for perfect agreement (as in the cases of voltage and current).

A Correlation Diagram is a device for showing graphically the amount of agreement. If one measurement is plotted vertically and the other horizontally, the amount of agreement is shown by the distribution of the points. When there is perfect agreement, all the points lie along a straight line. When the agreement is not perfect, the points fall within an ellipse, the less the agreement the rounder the ellipse. When there is no agreement at all, the ellipse becomes a circle. For any particular amount of agreement there is a characteristic shape of the ellipse, but this characteristic shape is distorted unless the range of values of both of the two measurements occupy equal lengths on the two scales. Some typical correlation diagrams are shown in the figure overleaf. When there is a smaller number of measurements than those shown in this figure, the characteristic shapes of the ellipses are less evident.

MONTHLY CHEESE PRODUCTION—Thousand Tons

MONTHLY MILK PRODUCTION—Million Gallons

Voltage
Current
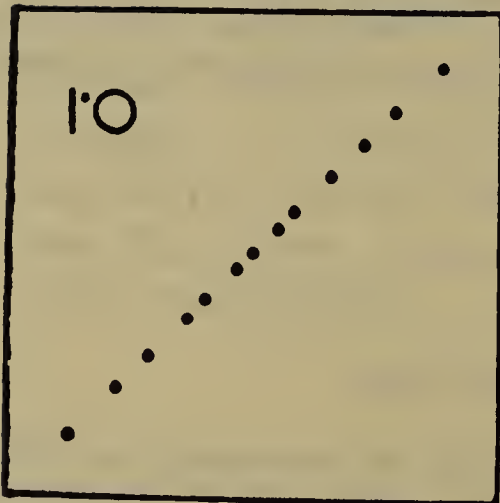
Mean Temperature
Hours of Sunshine
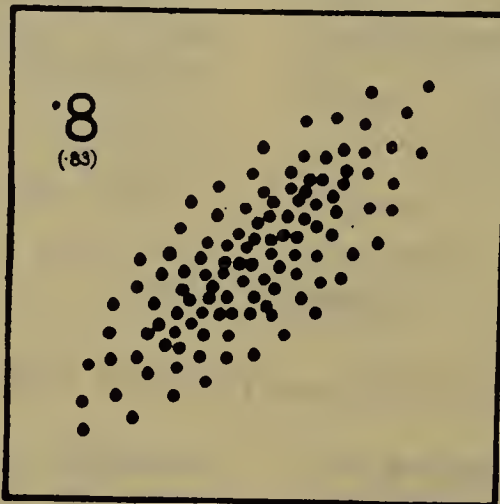
Height (Men)
Weight (Men)

Height of Father
Height of Son

Mean Temperature
Inches of Rainfall

Births per 1000 per mth
Deaths per 1000 per mth

APPENDIX C
ACADEMIC ATTAINMENTS OF TIME-EXPIRED APPRENTICES
TABLE C1
Most Advanced Academic Attainment of Time-Expired Apprentices

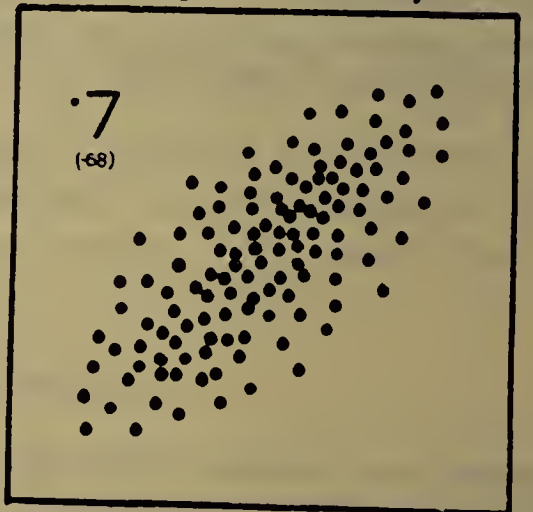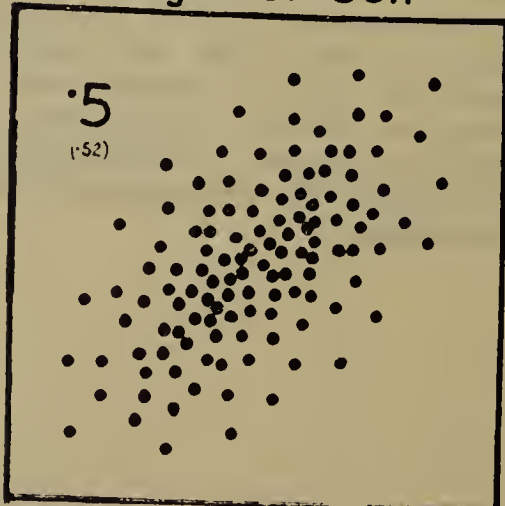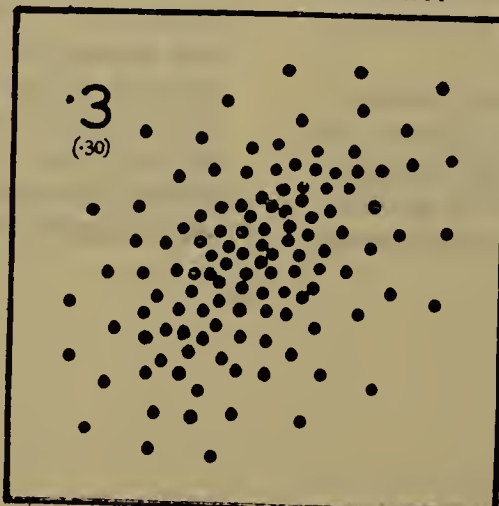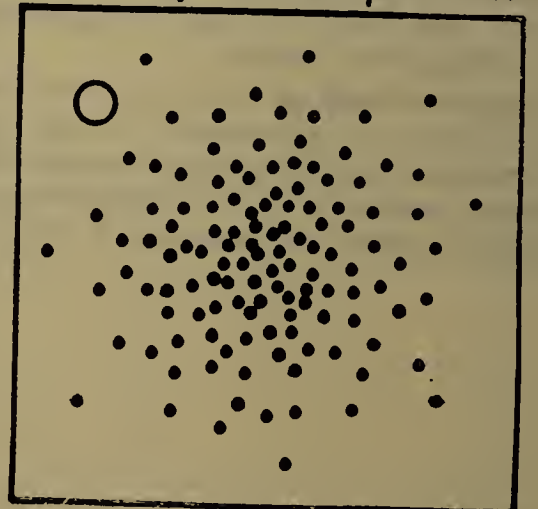|	Total Group	
	Craft	Student
Number of apprentices	1,862	303
Apprentices with no achievement..	155	4
Apprentices following National Certificate Courses	**1,180**	**296**
	Per cent	
Pre-National year	4	—
S1	18	4
S2	27	16
O.N.C. .. .. :.	24	20
A1	11	22
A2	12	21
Some higher qualification	4	17
Apprentices following City and Guilds Courses	**527**	**3**
	Per cent	
First Year	13	—
Second Year	27	—
Intermediate	33	33
Fourth Year	11	—
Final	16	67

TABLE C2
Summary of Most Advanced Academic Attainments in Terms of Educational Background of 906 Time-Expired Apprentices (Student and Craft) From 13 Firms

	Secondary Grammar	Secondary Technical	Secondary Modern
Number of apprentices and percentage of total group ..	249 i.e. 27.5%	187 i.e. 20.5%	470 i.e. 52%
Apprentices with no achievement..	11	8	70
Apprentices following National Certificate Courses	**191**	**143**	**178**
	Per cent	Per cent	Per cent
Pre-National year	0	1	8
S1	7	17	25
S2	26	29	34
O.N.C.	22	22	17
A1	22	10	8
A2	16	10	6
Some higher qualification ..	7	11	2
	100	100	100
Apprentices following City and Guilds Courses	**47**	**36**	**222**
	Per cent	Per cent	Per cent
1st year	10	11	19
2nd year	19	14	30
Intermediate	30	36	32
4th year	13	17	8
Final	28	22	11
	100	100	100

APPENDIX D

STATISTICAL APPENDIX

All the nineteen firms whose data were analysed had test scores available on which to base their selection, but they had other data as well, such as school records and estimates of character and disposition made at an interview. Each group of apprentices had been selected in some way and the amount of selection and the nature of the selection certainly varied from firm to firm. It would have been quite unjustifiable to treat each group as a random sample from a common population.

There were also differences between the firms in the incentives and opportunities for academic success given to the apprentices. These are reflected in the differences in academic achievement of the apprentices in the different firms. Tables D1(A) and D1(B) summarise the differences between the firms which can be expressed numerically.

Before any conclusions could be reached from the data as a whole, it was necessary to take account of these differences. By correlating the test scores of each firm with the criterion separately, the effect of the local differences, such as incentives and opportunity, could be eliminated, but the coefficients obtained would still be affected by differences in the ranges of ability as reflected in test scores and academic achievements of the candidates selected for apprenticeship. A correction for these differences can be made provided that the standard deviations of the parent population are known. It was decided to make this correction taking candidates for apprenticeship as the parent population.

It was necessary to obtain an estimate of the standard deviation of the score of each test for this parent population and also of the standard deviation of the academic criterion.

For the standard deviations of the tests all the available scores of the candidates were pooled. Actually scores from only fifteen of the firms were available. In the case of Group Test 36, 60E, 70, 70/1, 80 and 80A and the Mechanical Information test which were used by only a few of the firms, the number of scores available was very small and estimates of the standard deviations were obtained from other data in the Institute's possession. Correlations of these tests with the criteria are included in the tables only for completeness. The standard deviations used for the correction are shown in Table D2.

There was no direct means of obtaining the standard deviation of the academic criterion for the apprentice candidate population so it was decided to use the largest value in Table D1(A), 2·82, that of Firm R.

The raw correlations of the tests with the academic criterion are shown in Tables D3(A) and D3(B). The standard deviations of the test scores of the apprentices of the various firms are shown in Tables D1(A) and D1(B). The shrinkages σ/Σ of the standard deviations of the tests of the academic criterion are shown in Tables D4(A) and D4(B).

The corrections were made by the formula:

$$R_{12} = r_{12} \frac{\sigma_1 \sigma_2}{\Sigma_1 \Sigma_2} + \sqrt{\left(1 - \frac{\sigma_1^2}{\Sigma_1^2}\right)\left(1 - \frac{\sigma_2^2}{\Sigma_2^2}\right)}$$

except in the six cases in Table D4(A), where the 'shrinkage' is greater than unity, and the above formula would yield corrections involving the square root of minus one. In these six cases the approximate formula

$$R_{12} = \frac{r_{12}}{\sqrt{r_{12}^2 + \frac{\sigma_1^2}{\Sigma_1^2}\left(1 - r_{12}^2\right)}}$$

was used, which requires that only the shrinkage of one standard deviation (that in which the shrinkage is greater) should be known.

The corrected correlation coefficients are shown in Tables IA and IB of the text. The weighted means in the bottom line were obtained by the use of Fisher's z. The correlations of these tables show a great deal of uniformity; the differences are such as might be expected from the errors arising from the small size of some of the groups, but this may not be the sole cause of these differences. Correlating the scores from each firm separately eliminated local differences, such as the degree of encouragement given by the firm and the accessibility of a technical college, but there may be other local differences that were not eliminated in this way. For instance, in any one technical college the level of attainment required for a pass may be higher in one subject than in another, and as such differences will vary from college to college they may well affect the apparent predictive value of the tests. It was thought desirable to check whether the differences were greater than would be expected from the sampling errors.

If r is the correlation obtained with a finite number of cases and ρ is the parameter, there is a 31·7% chance that the difference between r and ρ will be as great or greater than the standard error of r and a 4·6% chance that it will be as great or greater than twice the standard error. This relationship was used for the check.

To make this check the parameter, ρ, of each test and the standard error of each is required. For any of the tests for which there is a reasonable number of r's, the weighted mean is a good estimate of the parameter. If the tests used by only a few firms are eliminated, there remain six tests (Group Tests 33 and 70/23, Form Relations, Vincent Models, Stenquist and R.V. Manual) for which there are thirteen or more coefficients. These tests were used for making the check. Small errors in the estimated parameters will not affect the result, as they are just as likely to increase the difference between ρ and r as they are to decrease it. As there is no formula for the standard error of a correlation coefficient corrected for restriction of range, the standard errors of the raw correlations were used.

There are 87 coefficients in Table IA among the six tests used, so that it would be expected that 28 (i.e. 87 × ·317) of the differences between ρ and r would be as great or greater than the standard errors, and 4 (i.e. 87 × ·046) would be as great or greater than twice the standard errors. The numbers found were 24 and 5, which is quite a close agreement. Thus the variations of the correlations coefficients of these six tests in Table IA are not greater than would be expected to arise from sampling errors. Any differences between firm and firm of the predictive value of these tests, if it exists, is masked by the sampling errors.

A similar check could be made with Table IB, but as there are only six firms in this table, the weighted means are much poorer estimates of the parameters, and as the number of coefficients is much smaller, such a check would be inconclusive. Also the distribution of the student apprentices on the academic criterion

scale, unlike that of the craft apprentices, is far from normal: see Table D5.

The weighted means of Tables IA and IB are estimates of the validities of each test used separately, but alone they give no indication of the over-all validity of the battery of tests. Most of the firms had used tests of all the types shown on page 1 of the text, but not all firms had used the same tests. Some tests had been used by only a few of the firms. The tests most frequently used were: Group Test 33, Group Test 70/23, Form Relations, Vincent Models, Arithmetic E.A.2, Stenquist and R.V. Manual. As can be seen from Tables IA and IB the validity of the R.V. Manual Test for predicting academic success is considerably lower than that of the other tests; as it would add nothing to the battery it was omitted from the analysis. This leaves six tests, and only five firms had used all of these six tests. The scores of these firms (F, G, L, P and Q) were pooled and the inter-correlations of the tests and the academic criterion were calculated and corrected for restriction of range. The coefficients obtained are shown in Table D6.

The multiple correlation coefficient obtained from this table is ·75. This is, of course, the optimum value obtained with the best possible weighting. To obtain a practical value, the beta coefficients were rounded off to the nearest whole number and the shrunken multiple correlation was calculated by pooling square; it was found to have fallen only to ·74. When, as is the case in Table D6, the inter-correlations between the tests are all comparable in size with their correlations with the criterion, there is usually very little shrinkage in the multiple correlation if equal weight is given to all tests. The multiple correlation when equal weight was given to each test was calculated by pooling square and found to be ·73.

Five of the correlations with the criterion in Table D6 are of about the same size, but the sixth, that of the Stenquist test, is much lower. As it was likely that this test added little or nothing to a battery for predicting academic success, a multiple correlation was calculated for the other five tests. With all tests given equal weight, this was found to be ·73.

As is evident from Table D1(A), the apprentices of these five firms had on the average a higher level of attainment on the academic criterion scale than those in other firms. This could be due to local differences of encouragement and opportunity, or it could be due to the apprentices of these five firms not being a representative sample of the whole. Table D7 shows that in the case of four of the five tests the level of test performance of the apprentices of the five firms was not very different from that of the apprentices of all the firms. Arithmetic Test E.A.2 was used by only two other firms, and so is useless for this check and has been omitted from the table. The differences in the means of the test scores of the four tests are small enough to justify the acceptance of the apprentices of the five firms as a representative sample. The multiple correlation coefficient obtained from the five firms can be accepted as applicable to the whole group.

FIRM	A	B	C	D	E	F	G	H
Total number of engineering apprentices for whom records of technical college achievement were available	70	144	128	116	111	111	50	28
No. used in main statistical analysis	70	125	128	108	101	110	48	27
No. passed no examination	17	3	10	26	7	15	1	2
On City and Guilds Courses: Total..	19	79	64	46	33	9	16	19
Passing City and Guilds Intermediate	5	64	22	29	7	8	8	14
,, ,, ,, ,, ,, %	26%	81%	34%	63%	21%	89%	50%	74%
Passing City and Guilds Final ..	—	15	—	12	2	1	—	—
,, ,, ,, ,, ,, %	—	19%	—	26%	6%	11%	—	—
On National Courses: Total	34	62	54	44	71	87	33	7
Passing O.N.C.	12	47	22	6	48	48	20	3
,, %	35%	76%	41%	14%	68%	55%	61%	43%
Passing H.N.C.	3	20	2	1	27	16	6	—
,, ,, %	9%	32%	4%	2%	39%	18%	18%	—
Academic Criterion: mean score ..	3·01	5·12	3·72	2·84	4·75	4·49	4·92	3·74
,, ,, standard deviation	2·31	1·86	1·78	2·11	2·58	2·57	2·08	1·58
Test results:								
G.T. 33 : mean score ..	97·5	—	—	98·6	101·8	107·4	108·5	99·3
: standard deviation	29·2	—	—	24·7	21·3	28·0	22·0	21·0
G.T. 36 : mean score ..	—	166·6	160·3	—	—	—	—	—
: standard deviation	—	22·8	22·1	—	—	—	—	—
G.T. 70 : mean score ..	—	—	—	—	—	—	—	41·5
: standard deviation	—	—	—	—	—	—	—	8·4
G.T. 70/1 : mean score ..	—	—	—	—	—	—	88·1	—
: standard deviation	—	—	—	—	—	—	17·6	—
G.T. 70/23 : mean score ..	25·7	29·9	25·4	24·9	22·9	29·5	26·5	—
: standard deviation	8·6	6·8	7·0	7·9	7·2	8·2	6·3	—
G.T. 80 : mean score ..	—	—	—	—	—	—	—	—
: standard deviation	—	—	—	—	—	—	—	—
G.T. 80A : mean score ..	—	—	—	—	46·1	—	—	—
: standard deviation	—	—	—	—	9·4	—	—	—
F.R. : mean score ..	31·7	33·9	30·5	33·1	—	37·5	31·3	32·0
: standard deviation	7·5	8·9	7·6	9·0	—	9·5	7·6	8·3
60E : mean score ..	—	—	—	8·6	—	—	—	—
: standard deviation	—	—	—	5·8	—	—	—	—
E.A.2 : mean score ..	—	25·0	—	—	—	22·9	23·0	20·4
: standard deviation	—	5·2	—	—	—	6·7	5·8	6·6
V.M. : mean score ..	29·9	35·8	27·8	28·2	26·9	35·3	34·2	34·8
: standard deviation	16·3	13·2	13·6	14·2	12·0	14·1	12·6	12·1
Stenquist : mean score ..	—	56·2	60·2	63·0	53·5	67·4	55·5	50·2
: standard deviation	—	19·2	18·1	17·9	13·4	17·7	20·5	14·8
Mech. Inf. : mean score ..	—	—	—	—	—	—	—	14·9
: standard deviation	—	—	—	—	—	—	—	5·9
R.V. Manual : mean score ..	—	69·8	82·2	65·9	64·6	71·3	64·3	—
: standard deviation	—	8·3	8·8	9·4	5·8	7·7	7·5	—

CRAFT APPRENTICES

I	J	K	L	M	N	O	P	Q	R	S	ALL
103	121	75	97	195	75	77	86	144	41	—	1772
70	119	61	97	190	75	69	78	144	41	—	1661
17	14	—	7	6	6	10	2	2	4	—	149
14	5	34	13	3	37	23	34	59	—	—	507
6	3	16	13	3	16	15	26	55	—	—	310
43%	60%	47%	100%	100%	43%	65%	76%	93%	—	—	61%
1	1	—	—	2	1	7	8	30	—	—	80
7%	20%	—	—	67%	3%	30%	23%	51%	—	—	16%
72	102	41	77	186	32	44	50	83	37	—	1116
28	48	29	30	72	18	12	38	69	16	—	566
39%	47%	71%	40%	39%	56%	27%	76%	83%	43%	—	51%
19	2	4	6	18	7	3	15	25	7	—	181
26%	2%	10%	8%	10%	22%	7%	30%	30%	19%	—	16%
3·70	4·24	4·91	4·34	4·44	4·06	4·13	5·12	5·83	4·15	—	4·41
2·39	2·08	1·69	2·11	2·19	2·07	1·73	1·84	1·49	2·82	—	2·22
105·5	105·3	101·7	102·5	109·8	109·4	101·2	103·2	112·2	115·2	—	
21·0	20·0	21·4	25·8	20·3	20·4	21·5	21·2	19·3	17·5	—	
179·4	—	—	—	—	—	—	—	—	—	—	
26·0	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	
91·2	—	—	—	—	—	—	90·0	—	—	—	
21·8	—	—	—	—	—	—	18·8	—	—	—	
—	—	29·5	28·0	31·4	29·2	23·8	29·1	31·0	—	—	
—	—	7·5	8·1	5·4	6·2	7·2	7·3	6·6	—	—	
42·3	46·9	—	—	—	—	—	—	—	—	—	
9·9	10·1	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	47·3	—	—	—	—	
—	—	—	—	—	—	9·4	—	—	—	—	
32·8	37·4	35·1	31·8	34·4	32·7	—	34·5	37·5	37·7	—	
7·7	8·5	8·1	7·3	8·2	10·3	—	9·0	8·1	8·6	—	
—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	
—	—	—	23·1	—	—	—	23·6	25·1	—	—	
—	—	—	6·6	—	—	—	5·2	4·9	—	—	
32·2	48·9	42·8	30·1	34·9	34·6	29·7	34·8	38·7	44·7	—	
11·7	7·5	13·7	11·9	12·3	12·9	10·9	14·5	11·8	9·4	—	
—	—	—	66·5	61·9	59·5	56·1	62·0	63·4	55·1	—	
—	—	—	17·1	15·4	20·1	12·9	18·4	15·6	13·3	—	
—	—	—	—	—	—	—	23·6	—	—	—	
—	—	—	—	—	—	—	5·1	—	—	—	
—	—	70·4	70·8	71·3	69·2	63·4	71·6	73·8	69·7	—	
—	—	8·7	8·3	8·6	7·6	8·2	9·5	9·4	7·6	—	

FIRM		A	B	C	D	E	F	G	H
Total number of engineering apprentices for whom records of technical college achievement are available ..		—	—	—	45	—	—	—	38
No. used in main statistical analysis		—	—	—	41	—	—	—	38
No. passed no examination		—	—	—	—	—	—	—	1
On City and Guilds Courses: Total..		—	—	—	—	—	—	—	—
Passing City and Guilds Intermediate		—	—	—	—	—	—	—	—
„ „ „ „ % „		—	—	—	—	—	—	—	—
Passing City and Guilds Final „ ..		—	—	—	—	—	—	—	—
„ „ „ „ „ % ..		—	—	—	—	—	—	—	—
On National Courses: Total		—	—	—	45	—	—	—	37
Passing O.N.C.		—	—	—	27	—	—	—	33
„ „ %		—	—	—	60%	—	—	—	89%
Passing H.N.C.		—	—	—	8	—	—	—	13
„ „ %		—	—	—	18%	—	—	—	35%
Academic criterion: mean score ..		—	—	—	5·73	—	—	—	6·74
„ „ standard deviation		—	—	—	1·64	—	—	—	1·77
Test results:									
G.T. 33	: mean score ..	—	—	—	125·2	—	—	—	125·5
	: standard deviation	—	—	—	16·0	—	—	—	17·3
G.T. 70	: mean score ..	—	—	—	—	—	—	—	55·6
	: standard deviation	—	—	—	—	—	—	—	8·2
G.T. 70/23	: mean score ..	—	—	—	34·0	—	—	—	—
	: standard deviation	—	—	—	6·0	—	—	—	—
G.T. 80	: mean score ..	—	—	—	—	—	—	—	—
	: standard deviation	—	—	—	—	—	—	—	—
F.R.	: mean score ..	—	—	—	43·6	—	—	—	40·4
	: standard deviation	—	—	—	7·2	—	—	—	8·6
60E	: mean score ..	—	—	—	15·5	—	—	—	—
	: standard deviation	—	—	—	4·8	—	—	—	—
E.A. 2	: mean score ..	—	—	—	—	—	—	—	28·0
	: standard deviation	—	—	—	—	—	—	—	4·5
V.M.	: mean score ..	—	—	—	41·8	—	—	—	47·7
	: standard deviation	—	—	—	12·5	—	—	—	9·9
Stenquist	: mean score ..	—	—	—	68·3	—	—	—	62·9
	: standard deviation	—	—	—	14·4	—	—	—	16·0
Mech. Inf.	: mean score ..	—	—	—	—	—	—	—	18·9
	: standard deviation	—	—	—	—	—	—	—	7.0
R.V. Manual	: mean score ..	—	—	—	67·4	—	—	—	—
	: standard deviation	—	—	—	9·4	—	—	—	—

STUDENT APPRENTICES

I	J	K	L	M	N	O	P	Q	R	S	ALL
—	98	—	—	—	25	—	—	—	29	29	264
—	98	—	—	—	25	—	—	—	29	29	260
—	1	—	—	—	—	—	—	—	2	—	4
—	—	2	—	—	—	—	—	—	—	2	2
—	—	2	—	—	—	—	—	—	—	2	2
—	—	—	—	—	—	—	—	—	—	100%	100%
—	—	2	—	—	—	—	—	—	—	2	2
—	—	—	—	—	—	—	—	—	—	100%	100%
—	97	—	—	—	25	—	—	—	27	27	258
—	78	—	—	—	24	—	—	—	22	22	206
—	80%	—	—	—	96%	—	—	—	81%	81%	80%
—	28	—	—	—	16	—	—	—	13	11	89
—	29%	—	—	—	64%	—	—	—	48%	40%	34%
—	6·51	—	—	—	7·72	—	—	—	6·38	6·90	6·57
—	1·77	—	—	—	1·31	—	—	—	2·58	1·77	1·89
—	133·4	—	—	—	137·3	—	—	—	132·8	122·1	
—	15·3	—	—	—	15·9	—	—	—	14·2	17·3	
—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	34·7	—	—	—	—	35·1	
—	—	—	—	—	5·6	—	—	—	—	5·8	
—	52·3	—	—	—	—	—	—	—	—	—	
—	7·7	—	—	—	—	—	—	—	—	—	
—	42·3	—	—	—	40·4	—	—	—	41·0	42·9	
—	6·7	—	—	—	10·2	—	—	—	9·3	8·1	
—	—	—	—	—	—	—	—	—	—	16·7	
—	—	—	—	—	—	—	—	—	—	6·7	
—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	
—	53·4	—	—	—	46·0	—	—	—	45·1	43·7	
—	5·7	—	—	—	9·0	—	—	—	9·5	8·7	
—	—	—	—	—	—	—	—	—	55·5	72·9	
—	—	—	—	—	—	—	—	—	12·6	10·0	
—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	69·9	—	—	—	64·8	76·8	
—	—	—	—	—	8·7	—	—	—	7·7	9·3	

TABLE D2
STANDARD DEVIATIONS OF THE TESTS TAKEN AS REPRESENTING THE APPRENTICE CANDIDATE POPULATION

Group Test 33	..	..	..	..	28·28
Group Test 36	..	..	..	..	28·09
Group Test 70	..	..	..	..	14·10
Group Test 70/1	..	..	..	..	24·32
Group Test 70/23	..	..	..	..	8·28
Group Test 80	..	..	..	..	13·00
Group Test 80A	..	..	..	..	12·85

Form Relation Test	..	..	..	9·68
Arithmetic Test 60E	..	..	..	8·00
Arithmetic Test E.A.2	..	..	..	6·84
Vincent Mechanical Models Test	..	..	15·72
N.I.I.P. Stenquist Test	..	..	..	19·54
Mechanical Information Test	..	..	7·52
R.V. Manual Test	..	..	..	..	9·80

TABLE D3(A)
RAW CORRELATIONS WITH THE ACADEMIC CRITERION
CRAFT APPRENTICES

FIRM	33	36	70	70/1	70/23	80	80A	F.R.	60E	E.A.2	V.M.	STEN.	M.I.	R.V.
A	·574				·642			·477			·550			
B		·491			·342			·336		·414	·333	·142		·003
C		·495			·306			·372			·268	·111		·049
D	·492				·441			·427	·635		·467	·296		·149
E	·440				·200		·140				·414	·178		·032
F	·541				·484			·235		·552	·571	·325		·026
G	·462			·548	·323			·530		·534	·393	·150		·037
H	·319		·379					·057		·357	·038	·300	·065	
I	·366	·311		·418		·313		·246	·418		·215			
J	·297					·311		·266			·377			
K	·392				·175			·195			·129			·014
L	·351				·405			·295		·558	·360	−·035		·068
M	·287				·228			·190			·261	·107		−·007
N	·259				·308			·253			·283	·186		·095
O	·186				·126		·060				·217	·221		−·084
P	·167			·228	·287			·418		·316	·284	·002	·438	·079
Q	·120				·216			·064		·307	·013	·111		·056
R	−·013							·315			·032	·195		−·131

TABLE D3(B)
RAW CORRELATIONS WITH THE ACADEMIC CRITERION
STUDENT APPRENTICES

FIRM	33	36	70	70/1	70/23	80	80A	F.R.	60E	E.A.2	V.M.	STEN.	M.I.	R.V.
D	·437				·503			·230	·550		·264	·176		·090
H	·070		·110					·100		·208	·269	·107	−·161	
J	·299					·270		·152			·104			
N	·151				·095			·420			·361			−·057
R	·168							·168			·325	·122		−·180
S	·272				·261			·195	·414		·072	−·044		·085

TABLE D4(A)

SHRINKAGES OF THE STANDARD DEVIATIONS (σ/Σ) OF THE TESTS
CRAFT APPRENTICES

FIRM	33	36	70	70/1	70/23	80	80A	F.R.	60E	E.A.2	V.M.	STEN.	M.I.	R.V.	ACAD. CRIT.
A	1·03				1·04			·77			1·04				
B		·81			·81			·92		·75	·85	·99		·85	·82
C		·79			·85			·78			·87	·93		·90	·66
D	·87				·95			·93	·72		·90	·92		·96	·63
E	·75				·87		·73				·75	·69		·59	·75
F	·99				·99			·98		·99	·94	·91		·78	·91
G	·77			·72	·76			·78		·85	·80	1·05		·77	·91
H	·74		·60					·86		·97	·77	·78	·78		·74
I	·74	·92		·90		·72		·80	·73		·74				·56
J	·70					·79		·88			·48				·85
K	·75				·91			·84			·87			·89	·74
L	·91				·98			·75		·96	·76	·88		·85	·60
M	·72				·65			·85			·80	·79		·88	·75
N	·72				·74			1·06			·82	1·04		·78	·78
O	·76				·87		·73				·69	·66		·84	·73
P	·77			·77	·88			·93		·76	·92	·94	·68	·97	·61
Q	·68				·80			·84		·71	·75	·80		·96	·65
R	·62							·88			·60	·68		·78	·53

TABLE D4(B)

SHRINKAGES OF THE STANDARD DEVIATIONS (σ/Σ) OF THE TESTS
STUDENT APPRENTICES

FIRM	33	36	70	70/1	70/23	80	80A	F.R.	60E	E.A.2	V.M.	STEN.	M.I.	R.V.	ACAD. CRIT.
D	·56				·72			·74	·60		·79	·74		·96	·58
H	·62		·59					·89		·65	·63	·82	·93		·63
J	·54					·59		·69			·36				·63
N	·56				·68			·95			·57			·89	·46
R	·50							·96			·60	·65		·78	·91
S	·62				·70			·84	·84		·55	·51		·95	·63

TABLE D5

DISTRIBUTION ON THE ACADEMIC CRITERION SCALE OF APPRENTICES WHOSE RESULTS WERE USED IN THE MAIN STATISTICAL ANALYSIS

Grade	Craft Apprentices	Student Apprentices
0	136	4
1	46	0
2	63	0
3	309	9
4	438	41
5	60	0
6	333	56
7	120	63
8	120	44
9	36	43
TOTAL..	1,661	260

TABLE D6

INTER-CORRELATIONS OF TESTS AND ACADEMIC CRITERION—FIRMS F, G, L, P AND Q: CORRECTED FOR RESTRICTION OF RANGE

	33	70/23	F.R.	E.A.2	V.M.	STEN.
Academic Criterion	·61	·54	·53	·64	·60	·36
Group Test 33 ..		·57	·44	·63	·60	·26
Group Test 70/23			·55	·51	·64	·33
Form Relations Test				·44	·59	·43
Arithmetic Test E.A.2					·55	·18
Vincent Mechanical Models Test ..						·43

Multiple Correlation Coefficient, R = ·75

TABLE D7

MEAN SCORES ON FOUR TESTS OF CRAFT APPRENTICES FROM FIRMS F, G, L, P, Q, AND OF CRAFT APPRENTICES FROM ALL FIRMS

Test	Mean (5 firms)	Mean (all firms)
Group Test 33	107·3	109·3
Group Test 70/23	29·3	28·4
Form Relations Test	35·2	35·4
Vincent Mechanical Models Test	35·1	36·4

Thomas of Fleet Street Ltd.
Printers . . . . London